Discussion.

The CHAIRMAN, in moving a vote of thanks to the Authors for The Chairman. their Papers, remarked that it was necessary to bear in mind that the natural difficulties of railway-construction were enhanced in a country like China by the absence of skilled labour, the distance from manufacturing centres, and the prejudice and superstition with which the natives were imbued. He had not visited China, but not long ago his attention was directed to the element of superstition when he was privileged to read a report by a distinguished Chinese statesman, who was supposed to have absorbed Western ideas of civilization. A river-embankment had been broken by a flood and a large tract of country had been deluged. Native workmen, under the control of a native engineer, had been sent to rectify matters; they had endeavoured to restore the condition of the bank by tipping in stone, and so on, but their efforts had not been very successful. They had thereupon returned and reported that the river-demon had made up his mind that they were not to be successful; that he was to be seen at all times of the day and night pulling down their work and thwarting their endeavours, and therefore they thought it was useless to do anything further. That report of a minor official was reproduced in a serious report by a statesman who was supposed to be free from the gross superstition of the ordinary native. Any Paper relating to China was of exceptional importance and interest at the present time, as engineers were looking to that country for great developments. They hoped that some settled form of government would be established which would enable such important work as the building of railways and harbours to be carried out, in order that the millions in China might be brought into closer touch with civilization.

Mr. J. W. SUTTON having exhibited, in the absence of Mr. Grove, Mr. Sutton. a series of lantern-slides illustrative of the construction of the Chinese section of the railway, observed that Mr. Grove had asked him to mention that the final costs under the main heads shown on p. 177, while remaining practically the same as to the total anticipated, were interfered with by the revolution in China in November, 1911, the consequent stoppage of traffic for 6 months and the destruction of many buildings, and so forth. As a consequence repairs had to be done, and some of the protection-works

Mr. Sutton. were deferred and would be completed in the present year. The line and works had been severely tested by a great flood in June and July, 1912, when the level of the water exceeded all previous records by 6 inches. For 10 miles through the large-bridge section the depth of water over the land averaged 10 feet, but there were no complete washouts, and trains ran almost as usual; the waterways proved adequate and the works sound.

Mr. Eves. Mr. G. W. EVES exhibited several lantern-slides showing the work done on the British section of the railway.

Mr. Waring. Mr. F. J. WARING congratulated the Authors on their very interesting and instructive Papers, but confessed that he would be glad to have a little more information on some of the matters dealt with, which he hoped the Authors would be able to give. He presumed that the curves and gradients on the British section of the line were the same as on the Chinese section, and would ask whether that was the case. He was rather surprised at the quantity of land it had been found necessary to acquire on both sections of the railway. On the Chinese section it appeared to be about 20 acres per mile, and on the British section about $23\frac{1}{2}$ acres per mile, which, roughly speaking, would give average widths of about 165 feet and 194 feet respectively. It appeared to him that this was a somewhat high average, even for railways on which the works were as heavy as they were in this instance; and in view of the high cost of the land, and the difficulty in acquiring it, he thought less might have sufficed. He thought there must be a misprint on p. 170, and that it should read: "The Loan Agreement called for the construction of a first-class double line" instead of "single line." He was pleased to notice that the economy gained by the use of low station-platforms had been recognized by Mr. Grove. He had often, in his own practice, urged this point; but the traffic-authorities had frequently been too strong for him, and had insisted on the higher platforms, which entailed — especially when the line happened to be on an embankment at a station—a great deal of unnecessary brickwork or masonry for raising the walls by the extra height. He thought it would add greatly to the interest and value of Mr. Boothby's section of the Paper if the Author would state the gross load per square foot allowed on the red marl on which the caissons of the East River bridge rested, and if he would give some description of the plant used in sinking them. As the concrete in the side walls of the wells or caissons was 5 feet 6 inches thick, there must have been a good deal of material underneath them which could not be reached by direct dredging; and he would like to know whether

any undercutting had been necessary, and, if so, whether any Mr. Waring. special tools had been employed in that work, as a great deal of difficulty was sometimes experienced in such undercutting. Possibly the material through which the caissons were sunk fell in of its own accord, and no special tools were necessary; but, if any had been used, he would like to know what they were. Depots had been formed, as he gathered from the Paper, both at the East River bridge and at the Tung Kun River bridge for erecting the girders, and that being so, it seemed to him to be rather strange that the caissons for the Tung Kun River bridge were erected on the East river and towed for 3 miles, which seemed to have been a peculiarly difficult and hazardous operation. Perhaps the Author could explain why the caissons for the Tung Kun River bridge were not put together at the depot which was formed at that bridge. It was not very clear to him whether the weights of the double octagonal caissons and the circular caissons included the well-curbs in each case, or whether the well-curb was additional. That information might be expressed more clearly. The weight of the completed span carried on the pontoons was, he gathered, 350 tons. It would add to the value of the Paper if information were given as to the dimensions of the pontoons and the number employed, because they must have been of considerable size to carry that weight and the staging on which the span was supported. He would also like to know the proportions of the concrete used in the steining of the piers. With regard to the British section, the cost of the railway was apparently about £57,000 per mile, which, in his opinion, was extremely high for any colonial railway, although the works were exceptionally heavy. The long tunnel seemed to have cost £136 per yard, which was a very high price for a single-line tunnel, even of so great a length. It would be of interest if the Author would give further information as to the machinery and drills employed the air-pressure, and the time occupied in driving the heading and completing this long tunnel. It seemed to Mr. Waring that the sinking of a shaft 250 feet deep—most of it, he supposed, through granite—must have occupied a long time, and perhaps the time occupied and the cost of this shaft (\$88,000) had been hardly warranted merely in order to obtain two additional working-faces in the heading. Had the shaft been retained for the purpose of ventilation, the case would have been different; but the Author stated that the shafts were plugged after the completion of the tunnel. Out of the long tunnel a great deal of granite spoil must have been obtained, and in view of the difficulty of obtaining ballast, to which

Mr. Waring. the Author referred, he thought a stone-crushing machine could have been economically employed, and the ballast afterwards distributed by rail along the line. The particulars of expenditure on the British section of the railway were very interesting and detailed, but if the Author would classify the main items in the same brief way that Mr. Grove had done in dealing with the Chinese section, it would place them in a more readily accessible form for reference, especially as details were not given of the cost of the whole of the tunnelling, but merely details of the cost of the longest tunnel. Referring to a statement on p. 203, it appeared to him strange that if the major bridges cost \$552 and the culverts \$494 per lineal foot of opening, the cost of the minor bridges should have been as high as \$921 per lineal foot of opening, and perhaps some explanation of this apparently excessive expenditure could be given. He desired in conclusion to make a remark about the credulity of Eastern peoples, a subject to which Mr. Boothby had referred. Many years ago he was engaged in India on the construction of a railway, in connection with which he employed a gang of about 200 women to break bricks for ballast, the bricks being obtained from an old ruined city. About 50 miles away the Government were building the Sutlej Canal, and at the headworks, which were of a very extensive nature, necessitating a weir across the river, a large number of Europeans and Eurasians were employed. The Bishop of the diocese was on tour, and he considered it his duty to visit the headworks of the canal in order to minister to the spiritual needs of the Europeans there. Very shortly after the visit the 200 women employed by Mr. Waring as ballast-breakers came to his house in a state of great excitement, and on inquiring what was the matter he was informed that the English engineers employed at the canal had been unable to get on with the work; they had therefore called for the advice of the Bishop, who had told them that it was quite hopeless to attempt to make the canal unless the blood of native children was used for mixing the mortar: the women therefore wished him to give them letters to say that they were in his employ, and that their children must not be sacrificed in that manner. He asked the women whether they had ever heard before of the British Government doing such a thing, or whether they had ever heard that he had massacred a child to carry on his work. They replied in the negative, and he thereupon told the women that the rumour they had heard was baseless, and before the Government took their children for the purpose they had mentioned, they would have to pass over his dead body; and that satisfied them!

Mr. R. J. MONEY observed that the two Papers possessed one **Mr. Money.** great advantage, namely, that the Authors had been both the engineers and the contractors of the works. The members, therefore, had not only descriptions of the works carried out, but also very full details of the cost, which, to his mind, added considerably to the interest and value of the Papers. Before dealing with the engineering details, he thought it might be worth while to take a brief survey of railway-construction in China up to the present date. The railway described in the Papers had been built in the extreme south of China, whereas the pioneer railways in that country had been built in the extreme north. The first railway in China was the Shanghai-Wusung, built many years ago as a little 2-foot 6-inch gauge line. It had hardly been opened for traffic when it was bought back by the Chinese and pulled up. It lay in that state for a long time, but was relaid to the standard gauge at a later date. The next start made in railway-construction was due to the resourcefulness, energy, and pertinacity of an English engineer, Mr. C. W. Kinder, M. Inst. C.E. Fortunately for Mr. Kinder he was backed by perhaps the strongest viceroy China had ever known, Li Hung Chang. Some coal-mines had been opened up in the north, and it was necessary to connect them with the coast. Mr. Kinder proposed a tramway (he did not dare to call it a railway in those days); but at the last minute the Chinese decided they would not have a railway, and that they must have a canal. As water could not be made to run up-hill, the canal was built as far as possible, and from its terminus up to the hills a little tramway was built, which the Chinese suggested should be worked by mules. Mr. Kinder was determined, however, that it should be worked by locomotives, and behind closed doors he built the first locomotive in China, taking the boiler from a steam-crane, the wheels from a tramway, and the rest of the engine from different parts of whatever machines he could lay hold of. After the engine was built he put it on the road to run. The Chinese did all they could to stop it, but they did not succeed, and, like Orientals in general, once it was an accomplished fact they said no more about it. Mr. Kinder, backed by Li Hung Chang, extended the railway little by little until at last he got it to Tientsin. The Chinese were then beginning to see the value of railways, and they agreed to allow him to extend it from Tientsin to Peking. That he did, and, with a view to make that piece of railway a standard and an object-lesson to the Chinese, he built a double line of railway through from Peking to Tientsin, equipped in the best style, with stone ballast, heavy rails, overhead bridges at some of the stations, signals, etc.

Mr. Money. That brought the history up a few years before the Boxer rising in 1900. Just before that Mr. Kinder had been pressing for a large extension of the Imperial Chinese railways which belonged to the Chinese Government, and a loan was raised in England for the purpose. Of the works proposed when the Boxer rising took place, only one piece had been practically completed, namely, about 80 miles of line running from near Peking to the south, and called the Lu-han Railway, which had been built by Mr. T. Johnstone Bourne, M. Inst. C.E., one of Mr. Kinder's lieutenants, who had hoped that Britishers would take up the concession for the line, which was the beginning of the Peking-Hankow railway. The English financiers, however, did not consider the terms sufficiently attractive; the concession for the line fell into the hands of the Belgians, who immediately proceeded to extend the line towards Hankow; and they were doing that when the Boxer rising occurred. The only other railway in course of construction at that time was the German railway from Kiao-chou to Shantung, inland. The Boxer rising brought railway-construction in the north to a stop. Further, the Boxers destroyed a large part of the Peking and Tientsin line, and some of the line running to the east. Just at that time Europeans seemed to awake to the possibilities of the future there was for railways in China, and they endeavoured to get concessions from the Chinese for those railways. He would not refer further to that subject, because there were gentlemen present who knew far more about such matters than he did; but one concession was obtained by the Peking Syndicate, who wanted a line to connect their coal-mines in Honan with the nearest waterway, and they had also in view a large extension of that line into other parts of China. As soon as the Boxer rising was over and the country had settled down, so that it was safe for foreigners to go into the interior, Messrs. Pearson and Son, who had been given the contract for the Peking Syndicate Railway, sent their engineers to build the line, and the Peking-Hankow railway was also proceeded with. In addition, the Germans continued to extend their railway to the west, and the Americans commenced the construction of the Canton-Hankow Railway in the south, but the concession was bought back by the Chinese when only 20 miles had been completed: and so matters proceeded for a few years after the Boxer rising. Mr. Kinder pushed on with his extensions, and eventually he built nearly 600 miles of railway. The next railway built after that was the Shanghai-Nanking railway on the Yangtse, and later the railway referred to in the Papers, the Canton-Kowloon. In considering the railway question, it was desirable to bear in mind the

size of China, which, roughly speaking, was about 100,000 square miles larger than the whole of Europe, if Russia in Europe and Norway and Sweden were excluded. In other words, from Peking in the north to Hong-Kong in the south, China was 1,500 miles long, and from east to west 1,000 miles broad. That gave some idea of the field there was for future railway-extension, if it could be proved, as he thought the members would hear it could be, that the main lines of railway in China would not only pay, but pay very handsomely. Turning to the engineering part of the Papers, it would be noticed that there was a very large difference between the costs of the two sections, the Chinese section having cost, fully complete with all charges, £12,700 per mile, and the British section £56,800 per mile. He would deal with the question of cost later on; but he mentioned the figures at this point in order to emphasize the relative importance in works of the two lines. The work on the British section was very heavy. There were the tunnels, the large reclamation-works to provide a terminal station of 39 acres, and the earthwork, a large part of it being in rock, and amounting to about 104,000 cubic yards per mile. When those figures were realized it would be seen that the line compared more nearly with an English railway than with an ordinary railway in foreign countries. In explaining why the line had cost so much, Mr. Eves stated that the Chinese coolies required a great deal of supervision. That was not Mr. Money's experience in the north—at least so far as earthwork was concerned. In bridge-work, masonry, carpentry, etc., the Chinese did require supervision, but if there was a thing in which they excelled it was certainly earthwork. During the building of the line of the Peking Syndicate, about 90 miles in length, the engineers were working against time, and as soon as the first 30 miles had been located and pegged out, they proceeded to let the contracts for the earthwork to four Chinese sub-contractors. No sooner had the contracts been signed than half the staff of engineers fell sick with typhoid fever and other illnesses, so that no engineering staff was available to supervise the Chinese coolies on the earthwork. Fortunately the sub-contractors and their foremen were experienced men. The sub-contractors were given a list of heights at each centre peg, in which was included the allowance for settlement, and in 3 months the earthwork was completed without a single engineer having supervised it. When, at a later date, an engineer was able to run his levels over the work, it was found that only in one or two places was the bank too low; in most cases it was too high, so that before the track-layers came along a gang had to be sent along to skim the earth off to the correct level.

Mr. Money. With regard to the difficulties encountered in constructing the big tunnel on the British section, he would like to ask Mr. Eves whether he had considered the question of using electric drills, or whether at that date they were not sufficiently advanced to make use of them. He knew that when electric drills were first introduced certain difficulties were experienced with them, but he believed those had been overcome, and that at the present time such drills were working very satisfactorily. Had that plan been adopted in the tunnel in question, the engineer would have found on completion of the work that, instead of being saddled with an expensive air-compressing plant for which he had been unable so far to find a purchaser, he would have had little difficulty in disposing of his electric generating-plant and a good deal of the other plant used in connection with the drilling. Mr. Eves's statement, that when the Chinese came back from South Africa all his labour difficulties ceased, was very interesting. Mr. Money had been waiting for some time to hear what the result of the importation of coolies into South Africa was when they were brought back to China. He was in China when the first coolies were sent to South Africa—in fact some men from his own work were sent; and although there was a great outcry at the time, and a good deal was heard about "Chinese slavery" and so on, he had been unable to see things in that light. The Chinese coolies who went out there had never in their lives received such good treatment or such high wages. In the north the engineers were paying the coolies 3*d.* per day, out of which they fed themselves; the same men went to South Africa and received a minimum wage of 1*s.* 6*d.* and their food in addition; and when they were put on piece-work, if they could make any more, they received it. It was very interesting to see from official publications in South Africa how rapidly the Chinese increased in efficiency. The Blue books stated that when the Chinese arrived in the country as inexperienced drillers they could only drill a few inches per day, but within 6 or 8 weeks they were able to do 42 to 50 inches, and even more, per day. A statement of the quantity of material moved per man per day, in the different kinds of material, and when from cut or borrow pit, would be valuable. Mr. Eves also said that his Shantung coolies developed beriberi, and could not stand the climate of South China. It would be interesting to hear from anyone who had experience of that what the cause of it was—if the cause had ever been discovered. A statement of the cost of the work in the tabular form in which it was given for the Chinese section would be useful, as it was difficult to ascertain the

total cost of the work from the Appendix. The cost of tunnel Mr. Money. No. 1 was not given, but it was stated that, although the easiest, it cost the most, because the contractor took risks. He rather thought "most" was a misprint for "least," because if the contractor took risks, he presumed the cost would be less than if no risks had been taken. Coming to the Chinese section, he noticed that formation-level was fixed at 2 feet 6 inches above the highest known flood. The determination of the proper height for the formation was one of the most difficult problems an engineer had to decide in a new country like China, where there were no written records. It was often found, before the works were completed, that the height that had been given as a record was exceeded by a flood such as had never been experienced in the memory of living man. It was therefore not sufficient to take the height of the previous flood, it was necessary to fix some height above it, and apparently from the Author's experience 2 feet 6 inches had been found satisfactory. The difficulties experienced in the purchase of land could not be escaped by any engineer who was responsible for carrying out works in China. The engineer laid out his line with the object of getting the flattest curves and the lowest gradients, but when he came to a graveyard—which he did in many places—he generally ran straight through it. He then handed his plan and the details of the land required to the land-purchaser, and left the Chinese to do the actual purchasing. They, however, were not influenced by the same ideas as the engineer, and they did not see why, when a graveyard was on the line of railway and the owners objected to the railway running through it, the line should not be taken round it. There was always a tussle between the engineer and the land-buyer as to who should give way. He had always found the question of graves a great difficulty in China, and at last a regular scale of payment was fixed—so much for a whole skeleton, so much for a skull, and so much in proportion for other parts. He had also found it necessary, when a graveyard was met with on the line of railway, to put a watchman over it, otherwise the graves were opened in the night and additional skulls were put in. The practice of turving soft cuttings and banks might sound rather extravagant for a new country such as China, but it was a practice of undoubted economy. He had seen it carried out even in Russia on parts of the Siberian railway, where very great economy was studied, the bridges being constructed of timber trestles. The means adopted to overcome the slip in the cutting at mile 58 seemed to have been very successful, judging from the fact that the work

Mr. Money. was subsequently tested by a flood, and stood the heavy rainfall perfectly. He hoped those who read the Paper would realize what the rainfall was, namely, 14 inches in 24 hours. The year 1912 was considered a wet year in England, yet the total rainfall in the whole of the year at Greenwich was only just double the rainfall in 24 hours in the cutting referred to; and the fact that the cutting passed that water and stood perfectly was a strong testimony to the methods adopted to overcome the difficulties there. It was very satisfactory to see that the rails came from the Hanyang Ironworks, near Hankow, the steel being inspected and passed by an English engineer as of excellent quality. The first visit he paid to the Hanyang Ironworks was at the time of the Boxer rising. He went across the River Han from the native city of Hankow, into the ironworks, and no sooner had he passed through the walls than he almost imagined he was in the midland counties of England. Blast-furnaces, rolling-mills, sidings, little tank-engines rushing here and there, created as busy a scene as any in the "Black Country." At that time the works were managed by three Europeans. Before the Boxer troubles broke out there were fifteen or more, but the majority left, and at the time he was there the works were being run by those three men. The late viceroy of Hankow, Chan-chi-Tung, who was a great Chinese patriot, had always taken a strong interest in the works and sought to develop them. Rails rolled in these works had been used on the Imperial Railways in North China, and on the Peking-Hankow railway; but they did not then give invariable success because the quality varied very considerably: sometimes the rails were too hard, and sometimes they were too brittle. He gathered from the Paper that those difficulties had passed away, and that satisfactory rails were now being introduced. The necessity of staff-quarters was a point wherein China differed from England; accommodation had to be provided for the whole of the workmen—not only the station-hands but also the track-men. Most of these men—the foremen, at all events—came from the north, or from some of the railways in Mid-China, and in the south they were looked upon as foreigners. Hence they could not live in the villages, and houses had to be built for them along the railway. Accommodation for fourteen men every 4 miles, that was, three and a half platelayers per mile, seemed however to be excessive. Whether it was due to a fact stated by Mr. Grove farther on, namely, that the labour in the south was very poor, he did not know; but an explanation on that point would be interesting. He was quite in agreement with Mr. Grove's arrangement of the platforms. He had often

wondered why, at the present day, when long bogie-carriages with Mr. Money. end entrances and steps were in vogue, railway-companies should go to the expense of building high platforms. When, as often happened in China, a station was on a bank, the cost of the platforms was very heavy. In many places on the Continent the platforms were only 6 inches above rail-level. He would like to know why the engineers, having adopted that principle at most of the stations, had not carried it right through and built a low platform at the terminus. He also approved the Author's practice of making halt-buildings so that they could be moved. It was very difficult to tell, when a line was built, how the traffic would develop, and it was much better to put up cheap or temporary buildings for stations, and later on to build permanent stations out of revenue. He would like to ask whether the interlocking semaphore signals were not an unnecessary refinement. Except on the Peking-Tientsin line, Mr. Kinder had never considered it necessary to use such apparatus. At one time the pointsmen often lost their heads and threw the points over as the train was passing, splitting it in two; but Mr. Kinder overcame that difficulty in a simple way. He drilled two holes in the tie-rod connecting the two switch-points, and put a bolt through, which engaged with a casting on the sleeper below; then, so long as a train was passing over, the points could not be shifted. If the pointsman changed his mind as the train was approaching after the road had been set, he had to step in front of the approaching engine and pull the bolt out before he could shift the points; and as he ran a great risk of being run over, he did not do it. As he had already remarked, the British section had been very costly, which fact Mr. Eves attributed to the tunnels, the reclamation, and the extensive plant required. The total cost was £56,000 per mile, whereas the Chinese section cost £12,000 per mile. Taking the Chinese section as a better average, and eliminating the rolling stock, it would be found that the cost for works was £11,000 per mile. Even that seemed to him very heavy compared with the cost of railways in North China. Mr. Kinder had stated that the first railway he built in North China cost £2,800 per mile; the next, the Lu-Han railway, cost £5,300 per mile: and the line between Peking and Tientsin—a double line equipped in first-class style, with stone ballast, points and crossings—only cost £10,000 per mile. Personally he had built a railway up in Honan, for Messrs. Pearson and Sons, for £5,400 per mile, although it was 400 miles in the interior, away from a port, and the district was frozen up for 3 months in the year, during which time there was no communication

Mr. Money. with the outside world except through the post. Compared with £11,000, the latter figure showed a big difference. He would like to know whether that was due to the higher cost of labour in the south, for which Mr. Grove had given some figures, or whether it was due to the superior equipment and the higher standards adopted for the railway.

Mr. Moore. Mr. R. ST. GEORGE MOORE remarked that his principal work in China had been connected with waterworks, but inasmuch as many engineering operations were the same for waterworks as for railways, he hoped some account of his experience might be in order. He wished first, however, to refer to a remark made by the last speaker. Since Mr. Money visited the Hanyang Ironworks the plant had been entirely renewed. The old Bessemer plant, which was incapable of dealing with the amount of phosphorus found in the ore, had been removed, and an open-hearth process had been introduced, giving excellent results, as Mr. Grove stated in his Paper. He had made numerous tests of rails made in these works, and had found them quite satisfactory. He would like to call attention to the engineering which the Chinese themselves were capable of doing. That they could carry out certain works had been fully demonstrated. As adviser to the Viceroy of Hupe and Honan, he had come in more immediate contact than many foreigners in China did with the engineering work that the Chinese were trying to do without foreign assistance. To take a case in point: behind the residence of the Viceroy, in the capital city, Wuchang, there were three large lakes, the water-level of which was below the summer-level of the Yangtse-kiang; and, in order to empty the lakes, some scientific arrangement was required in the shape of a water-gate. A water-gate had been built three times by the Chinese, and each time it had tumbled down. On his first visit to China, in 1905, one of the first things the Viceroy asked him to report upon was the work that was being done in connection with that water-gate. The people he met in connection with that report had now passed into history. The two men who were deputed to meet him were General Pieow, the first general to be killed in the revolution by a bomb, and the other was General Lee, who was assassinated towards the end of the Revolution. The work they were carrying out, in excellent fashion, was a siphon over a puddled bank, to relieve the pressure pending the reconstruction of the water-gate. In 1907 he was again asked to examine the work, and he found that a water-gate was being constructed, the above-ground structure of which was founded on quite modern principles. Where the Chinese failed, however, in that instance was in regard to the necessary foundations. They were

making the same mistake as they had made in the earlier days, Mr. Moore. namely, piling the foundations without having ascertained the carrying-power of the ground. He advised that the strength of the foundations should be doubled, which was done, and he believed the water-gate thus built was now standing well. The upper part of the structure was the most interesting piece of masonry work he had ever seen carried out by natives. It was of wrought granite, very scientifically dove-tailed, and was erected temporarily on the ground beside the site. Passing to another point, in 1906 the Viceroy Chang-chi-Tung, one of the most progressive men in China, decided to stop the flooding of the country behind the large town of Hankow. He decided to build a bund or bank around it, and in 4 months, with coolie labour, a bund 17 miles long, 25 feet wide, and averaging 15 feet high, was built. Mr. Moore had walked round the bund, and found that it had stood perfectly; it resisted an exceptional flood in the following summer, when the water rose to at least 8 feet above the toe of the bund. On the River Yangtse, the whole front of the town of Wuchang was protected by a red sandstone wall built on thoroughly scientific principles. About 50 miles above Wuchang there was a very awkward cross current which evidently caused great difficulties, and at that place a highly ingenious mole had been built. With regard to the capabilities of individual natives, he had on one occasion to build a water-tower, and he did his best to persuade the Chinese to employ one of the Shanghai contractors. They would not agree to his suggestion—though they allowed him to get all the material made in Shanghai and shipped to Hankow—saying that if the contract was let to a European, one European and a number of Chinese would be employed, and they did not want that one European. The company finding the money was a Chinese one, there being no loan agreement and no influence brought to bear, such as occurred in railway matters. The tower was built of wrought and cast iron sheathed with brickwork, and was erected with extreme accuracy, being a piece of highly skilled work. He also noticed that the fitters erecting the machinery were very capable. Passing to the particular subject of the Papers, his connection with Chinese railways had only been sufficient for him to realize the problems to be solved, which, he thought, related to three matters—location, length of bridges, and length of spans. Location in China was extremely difficult, because it was not a new country like America, where the railway could be located along the line of least resistance. He might mention incidentally that that was exactly what the Americans did when

Mr. Moore. Mr. J. Pierpont Morgan held the concession for the Hankow-Canton railway. In the course of his work he came across the old surveys, and he found that towns and trade routes that had existed for 1,000 years had been ignored because they did not fit in with the line of least resistance. On the other hand, the Japanese, who succeeded the Americans in locating the railway, went in for excessive curvature and deviation, and in order to avoid a small amount of work they put in long deviations and back shunts. For example, a town called Yanglutung, which was the collecting-point for the tea-trade of the Province of Hupe, was in a difficult situation for railway purposes, and it was omitted from both the American and the Japanese survey. The same thing occurred in connection with Ching-lin-chee and Yochau, the last port on the Yangtse before the entrance to the Tungting Lake; they were omitted and a back shunt of 4 miles was put in. He desired to add another railway to the very interesting list given by Mr. Money, namely, the Kalgan railway, which was one of the most interesting pieces of railway-construction in the whole of China. It took the place of the old camel-route through the pass, and had very heavy gradients; and eventually it would be extended across the desert. With regard to the length of bridges, Mr. Grove said that each river had been bridged completely as to its waterway including the foreshore, between the water and the side defence-bund or bank, but he did not state how he had satisfied himself as to the accuracy of the Chinese definition of the width and depth of channel required. On the northern or Hupe section of the railway there were a number of cases in which the engineers had not the advantage of the waterway being defined, it being largely a matter of guesswork. That it was a matter of considerable uncertainty was demonstrated by the breaches that occurred both in the Japanese railways and in the Chinese railways in the years 1907 and 1908. In 1907 the railway between Yokohama and Tokio was breached in two, if not three, places, and that between Tokio and Kioto in six places. The Hankow-Peking railway was breached in three places; the Imperial North China railway in one place; and the German railway from Isingtau to IZanan-fu in at least one place. That demonstrated, from the experience of Mr. Kinder, the Belgian engineers, and the German engineers, that it was very difficult to define the width of bridge necessary at each waterway. He wished to ask how Mr. Grove had arrived at the conclusion that 224 feet was the most economical span. It seemed to him that, considering the depth of foundations and the difficulties connected with them, 224 feet, with girders costing £20 per ton, was rather a long span. He would also

like to know whether the 100-cubic-foot unit to which Mr. Grove Mr. Moore. referred was based on the Chinese foot (100 cubic Chinese feet being 1 fong), or the English foot. The Chinese foot being 14·1 English inches, there was a considerable difference between 100 English and 100 Chinese cubic feet. Lastly, there was one professional question to which he wished to allude, namely, the cost of the engineering part of the railway described by Mr. Eves. He thought the engineers must have been underpaid, because in the summary of costs the salaries of the engineers and their indoor office-staff was 2·9 per cent. of the total, and the consulting engineers' fees and home office-expenses, 1 per cent., making a total of 3·9 per cent. He was sure that was too little.

Mr. A. H. OUGH desired to say, before proceeding to discuss the Mr. Ough. Papers, how much he regretted the death of Mr. Edward Sargent Lindsey, M. Inst. C.E., who succeeded Mr. Eves in charge of the British section. He had had a great deal to do with Mr. Lindsey in various ways, and had been struck by his great energy and capabilities. Mr. Lindsey was a man who never spared himself, and in fact if he had worked a little less hard in China he might have been alive still. Mr. Grove referred to the necessity of keeping down the cost of the railway on account of competition with the river-steamers owned by European lines, and had some doubts as to whether the line would eventually succeed in overcoming that competition. When Mr. Ough left Hong-Kong, in November, 1912, the steamship company was paying a reduced dividend, and its stock was much below the usual figure. It was said that that was due to the extraordinary competition by Chinese steamers, but he thought it was due partly to the competition of the railway. Travelling along the line, as he had frequently done recently, it was encouraging to notice the number of houses that were being built all along the route, the growth of the villages, and the general improvement in the appearance of the buildings and of the country generally on each side of the line. Reference had been made to the difficulties connected with land-acquisition. He had adopted at Swatow in 1912, after experiencing a great deal of trouble with graves, a plan which he thought might be useful. He set out very carefully a length of pipe-line, put up sight rails, and installed an armed guard to look after them. As soon as they were destroyed, he put them up again, keeping the guard there all the time. Meanwhile he put in the pipe itself half a mile away. Mr. Grove did not explain why dynamite was a valuable commodity; the reason was that it was used extensively for fishing. It involved great risk to the fisher-

Mr. Ough. men, and its utility for this purpose was a great nuisance to the engineer, who had to conserve his stock of dynamite. With regard to slips in cuttings, he did not agree with either Mr. Grove or Mr. Eves in the slope they had adopted, which he thought he was right in saying was 1 to 1 in the soft. His practice in Hong-Kong, working in the same material, had been to cut it out to as steep a batter as it would stand—vertical if possible—and line it. Where it was necessary to batter back to $\frac{1}{4}$ to 1, the slope was plastered to keep the rain off it. Turf would not grow on the sides of cuttings, although it would on banks. Where the ground was not good enough to hold up, it was necessary to cut back to about $\frac{1}{2}$ to 1 or $\frac{3}{4}$ to 1, and personally he did not agree with 1 to 1 slopes. They were so flat that the rain had a serious effect upon them; in fact, he knew from experience that in one night rain would eat 10 feet into such slopes in places, and the whole of the face would fall in in a few hours. Turfing the banks was absolutely necessary, on account of the heavy rainfall. It might sound like exaggeration, but it was a fact that on one occasion within his own knowledge 27 inches of rain fell in Hong-Kong in 24 hours. That occurred in May, 1889. It washed some buildings into the sea. Mr. Boothby referred to the difficulty of getting good contractors, and advocated the departmental method of carrying out work. He was sorry he could not agree with that entirely, though he agreed to the extent of admitting that it was not easy for an engineer who was a stranger in the country to get good contractors. The Chinese were very curious people. A foreigner had to establish his own character himself. It was no use his going to China with money for the purpose of putting up buildings, or carrying out large works, in the expectation that the money would produce the labour. A Chinaman would not work for a man until he knew something about him, whether in domestic service, or as a coolie, or as a contractor; so that people who had lived in China for a number of years were able to do things, in the way of procuring men and getting work done, that a comparative stranger had very great difficulty in accomplishing. Certainly he could not possibly get work done at the same rate, either of time or of money. In South China, which included Canton and Hong-Kong, the sub-letting of contracts was universal. Many contracts were sub-let three times before they were signed. For example, a contract was given for a large breakwater for the purpose of sheltering the small craft in the harbour during typhoons. He happened to know that, before it was signed, that contract was sub-let twice, at a very large reduction on the actual amount contracted for. The man

who signed the contract pocketed a profit of about \$25,000 on a Mr. Ough. contract for about \$1,000,000, having sold the contract before he signed it. The same thing was done in nearly every instance; it had been done with many contracts that Mr. Ough's own firm had entered into, and the only way to get work done was to recognize the fact, and to meet it with a certain amount of guile. The engineer selected the contractor who had the most reliable staff of sub-contractors at his command, or rather he selected the sub-contractors and found out for whom they were working. By a process of elimination half a dozen good men were put on the list, and the work was done at fairly good rates. Another very practical and essential point was that the engineers' specifications should always be written in Chinese as well as in English, and that meant having one or two reliable interpreters in the office who could be depended upon to put the English specification into the vernacular—into such Chinese as the more or less educated contractor could understand. When it was borne in mind that a Chinaman who knew 2,000 characters in his own language was considered a very learned man—equal, say, to a person who knew about half the English language—it was evidently no use drawing a specification in terms of which he could make neither head nor tail. It must be put into such simple language that the contractor could thoroughly understand it, and, when that had been done, the engineer had gone a long way towards success. The erection of one bridge at the end of the British section of the Canton-Kowloon railway was let to a person named A. King, a well-known man in Hong-Kong, who looked after the yachts. He had a little slipway and an old diving-dress or two, but knew nothing whatever about riveting or the erection of steelwork. Nevertheless, that man obtained the contract to erect the bridge, and he did it. The way to get a bridge finished in China was to let the contractor complete it in his own way, without condemning any rivets; because, the moment the engineer condemned half-a-dozen rivets, the contractor stopped work. It was best, therefore, to let him finish the bridge; then the engineer could cut out half the rivets, and make the contractor do them over again. In fact, the best way to treat a Chinese contractor was to let him go his own way so long as he was not doing any great harm, and when he said he had finished, then to cut his bad work to pieces. Mr. Ough had done that with the Swatow water-tower, a 150,000-gallon tank, 85 feet high. When the sub-contractor had finished the work, 25 per cent. of the rivets were found to leak. He was made to cut them out and do them again, and the tank was now excellent. Mr. Ough thought that one of the principal reasons

Mr. Ough. why Mr. Boothby had experienced difficulty in keeping down his costs was the fact that he let his work in fongs, i.e., 100 cubic Chinese feet. His firm had been engaged on engineering work in China for 30 years, and they and other firms had taught the natives to work to English yards and English cubic feet, using English 2-foot rules. They understood English measurements very well indeed, but they did not understand 100 English cubic feet as a unit. The contractors signed a contract with English engineers at a rate per 100 English cubic feet, and they immediately sub-let it at 100 Chinese cubic feet. The Chinese lineal foot was 14.1 inches, so that an English cubic foot was 0.55 of the Chinese cubic foot. The contractor thus made 45 per cent. profit on the first sub-let. That also might sound like exaggeration, but he could show the truth of it by stating some facts that had come within his own knowledge. Two of Mr. Eves's sub-contractors had a dispute over one of the bridges and went to law. As the magistrate could make nothing of the various measurements, he suggested that the matter should be referred to somebody who understood them, and Mr. Ough was selected as arbitrator. He settled the question by making the employer pay on his Chinese contract, which was in Chinese cubic feet. The man who had actually done the work was very angry indeed, because he had thought he would be paid on the same measurement as that on which the engineer paid the original contractor, which was in English feet. When he found he was only to be paid 55 per cent. he was exceedingly annoyed, but he had to put up with it, because the contract in Chinese was worded in that way. Passing to Mr. Eves's Paper, the Author modestly described the railway as an ordinary hill railway. Mr. Ough did not agree with that; he thought it was an extraordinary hill railway. At the terminus the railway was practically on the surface, then it went up a bank on a gradient of 1 in 100, and straight into a cutting 169 feet deep. That was no ordinary cutting; in fact, he thought there was only one deeper in the world, namely, the Culebra cut on the Panama Canal. To deal with such a cutting required very serious consideration. It gave Mr. Eves a certain amount of trouble, and he would be interested to hear that since he left nearly all the soft slopes had been lined with rough ashlar. He ventured to suggest that, if Mr. Eves had worked to $\frac{1}{2}$ to 1 instead of 1 to 1, much less trouble would have been experienced in the cutting with slips. He wished also to comment on the location of the line. He did not think it was the Author's fault that the line went straight into

the hill; he believed it was ordained by higher powers that Mr. Ough. the centre-line must be adhered to, and therefore the Author had no option. The line which he walked over about 30 years previously, and which he still preferred, was one taking a much more southerly course; it would go through Kowloon due west instead of north-west, and would come to the same crossing at Sham-chun, where the two sections met, or perhaps a little lower down the river. He thought a better, though longer, line would have been obtained that way. Quite as good gradients would have been obtained, less work would have been involved, and the long tunnel would have been avoided. Previous speakers had commented upon the high cost of the British section; but the cost was not surprising to those who had been on the spot and knew the circumstances, and he thought Mr. Eves deserved great credit for getting the work done for the money that had been spent. Mr. Eves had had to deal with the Public Works Department of Hong-Kong, which insisted on treating the dreary waste of sand-hills at the back of Kowloon as if it had been Hampstead; they required him to build platforms at Yaumati exactly similar to those on any first-class line in England, where the Board-of-Trade requirements were fully carried out. That cost a very large sum of money beyond what the work would have cost as a pioneer line. Again, they made him provide for 100-foot roads, and for spans of 80 feet over roads which were not metalled, and which were only about 8 or 10 feet wide in the actual working part, the rest being waste. They imagined a dream city for the line to go through, involving an extraordinary amount of work, which many in the colony deplored, because they felt they would have to pay for it. With regard to the reclamation of more than 39 acres, they had been told that the reason for going straight into the deep cutting was in order to get material for the reclamation. He suggested that had the person who located the line made a few local inquiries, or had any local experience, he would have found it quite possible to obtain the necessary material elsewhere. There was no need to go into a 160-foot cutting simply to get "muck" for the reclamation, because, if there was one thing that could always be found in Hong-Kong, it was "muck." Mr. Eves bewailed the cost of the granite ballast, but Mr. Ough did not think he was to be sympathized with in that respect. He had been trying for the last 2 years to sell a large mass of granite which he obtained out of Kowloon Dock, and could not get a purchaser for it. He had offered beautiful white granite at 70 cents per cubic yard, which was cheaper than Mr. Eves's price. All granite had to pay a royalty

Mr. Ough, to the Government. The site of the terminus had not been decided when the Author left, but it had now been fixed at the extreme point of Kowloon peninsula, where the ferry went across to Hong-Kong. The Government had paid \$4 per square foot for the land, which was practically the same rate as that at which they acquired other land in the same neighbourhood 2 or 3 years before. The reclamation consisted of 40 acres, and there was berthage for only one ocean-going steamer drawing 27 to 30 feet of water—or at the most two. If they built jetties to get out into deeper water it would be necessary to go a long way out, and the tide round the point was a 4- or 5-knot current. Steamers would therefore experience great difficulty in berthing, and would not go there. Moreover, in building such jetties the Government would be competing with private enterprises established on land bought from the Government and developed close by on the other side of the peninsula, where every ocean-going steamer that came into the harbour could be accommodated with ease. Both Mr. Money and Mr. Moore had delivered a kind of panegyric on the Chinese coolie. He confessed that he did not know anything about northern coolies, except that he had seen them from train-windows and carrying cargo at Shanghai; but he did not admire the southern coolie. His firm, which had employed large numbers of them, had found them very difficult to keep sanitary. They had also found that with anything over 500 coolies at work it was necessary to organize what was called a “flying gang.” When a piece of work was being proceeded with very slowly, thirty or forty picked men, who received better money, were put on to that particular piece of work over the other coolies. It frequently had to be done by strong persuasion. The bulk of the coolies saw what could be done in the time by picked men, e.g., the filling of a 5-cubic-yard wagon. The wages of the men were charged to the sub-contractor, who was credited at his contract rate with the material put into the truck for him. After a few lessons of that sort, a sub-contractor generally got rid of all the decrepit individuals who had been posing as coolies, and put on men who could work. The difficulty was that when a contractor obtained a contract he immediately put all his relatives on to the work; male or female, adults or infants, they all seemed to find something to do; and the result was that the place was crowded with people, not more than 25 per cent. of whom were doing any useful work. They also got in the way when blasting-operations were being carried out. Some Indian labour had been tried, but he had not found it at all satisfactory. The Indian

seemed to get homesick, and he preferred softer jobs; he would rather do tailoring or money-lending than use a pick. On trains on the Siberian Railway and in other places he had met a great many returned Chinese coolies from South Africa, and had noticed that they all seemed exceedingly prosperous. They wore fine clothes and jewellery, some of which appeared to be quite valuable; and he had not found one man who would not go back to South Africa if he had a chance. Another drawback in the Chinese labourer was that he could not use a shovel. The southern coolie did not get his knee in behind the shovel, and did not perform anything like the amount of work that an ordinary navvy would get through. The natives also objected to the use of plant. If an engineer tried to help them with steam-cranes, or anything of that sort, the coolies generally found some means of putting the cranes out of action, or losing some of the parts. They derailed the locomotives if they possibly could. Their object in doing so was to make more work for the basket coolies. Nearly everything in China was carried in baskets. Rock, when blasted, had to be broken into pieces weighing not more than 30 lbs., so that it would go into a basket, and a coolie would pick up two of the baskets on a bamboo and walk away with them, or two coolies would carry one piece of, say, 2 cwt. To have to break rock to such a small size was a serious matter, and the engineer naturally wanted to use a crane for getting some of the large pieces away. But the coolies did not like it, and it was with the greatest difficulty that a crane could be used. He would like to point out to English manufacturers that it was impossible for engineers in China to use the English pattern of small hand-tip wagon. Everywhere in Hong-Kong Koppel wagons were used. The Kerr-Stuart wagons were very little used for hand-working, because they were so designed that they would not tip. They were too well-made and too heavy; it was difficult to get a full load into them, and, when it was in, it could not be tipped by one man. The coolies did not like them and would not use them. Both the coolies and the foremen—the latter especially—preferred wheelbarrows, because they could sit in the shade, listen to the squeaking of the wheels, and know that the men were working. The southern coolie had many good points: he had a keen sense of humour, and could be persuaded by an appeal to it to perform unwonted feats; he would work on a face 150 feet above the wagons, where a navvy would not go without a rope, and on scaffolding of the flimsiest nature. He did not get intoxicated, and cost little to feed. Experience showed that coolies were best housed in matsheds built on poles over sea-water, wherever possible.

Mr. Ough. The disease called beriberi, due to the use of polished rice, could be combated by changing the location of the matsheds. Malarial fever, due to mosquito-bites, could be largely prevented by surface drainage and avoidance of stagnant water, in which the insects bred. Mr. Eves compared the cost of tunnel No. 1, built by contract, with that of Nos. 2, 3, and 4, built departmentally; it would be interesting to have the cost stated per lineal foot of each of these tunnels, excluding the portals, as it was not possible to compare a tunnel 150 feet long with two double-line portals, such as No. 1, with one $1\frac{1}{2}$ mile long with two single-line portals, such as No. 2.

Mr. Brennan. MR. BYRON BRENNAN remarked that, whilst he knew nothing about engineering, he had lived in Canton for several years, and knew almost every inch of the ground over which the railway passed. When he first heard that a railway was projected from Hong-Kong to Canton he thought it was a great mistake, as the facilities for water-traffic were such that the railway would have no chance of paying; and he was still of that opinion. There was also the danger that the Chinese would be sorely tempted to develop a new terminus at the expense of Hong-Kong. As the members knew, Hong-Kong was British, and Canton was in Chinese territory. Below Canton was Whampoa, which at one time was a very large port. He believed that sometimes in the sixties there were two hundred sailing ships anchored there at one time. The port was still there, but it was not much frequented, although steamers drawing 24 feet of water could use it. It required only 1 or 2 miles of railway to make Whampoa a great rival to Hong-Kong, quite apart from the natural desire of the Chinese to have the southern terminus of the huge trunk lines coming from Peking, 1,500 miles to the north, across the Yangtse to Hankow, and through Hankow to Canton, on Chinese land rather than in Hong-Kong. There were several ways in which that result might be achieved: one was by giving greater facilities in the way of rebates; but the greatest lever they had was in the matter of customs duties on goods leaving China. Those who were unacquainted with the state of affairs in China might not know that a large portion of the trade of Canton was with other parts of China. At the present moment, goods leaving Canton for the north—say, Tientsin—would have to pay an export duty of 5 per cent., and, on reaching any of the ports of China, a reimport duty of $2\frac{1}{2}$ per cent. Although steamers leaving Canton passed through Hong-Kong, a non-Chinese port, they were still treated as coasting steamers if their destination was a Chinese port. Goods going by rail from Canton to Hong-Kong would be leaving the country at the frontier, and there would be

some kind of Custom-House arrangement whereby they had to pay Mr. Brennan. 5 per cent. export duty. If at Hong-Kong they were shipped, the Chinese Customs authorities lost sight of them; and on entry into any other port in China they were treated as foreign goods and had to pay an import duty of 5 per cent. That was quite sufficient to prevent any goods produced in the Canton province, or in the province just north of it, from being sent by rail to Hong-Kong. The people would rather put them on steamers in Canton and send them direct without breaking bulk in Hong-Kong. Another great difficulty he foresaw was that Hong-Kong was a very small colony, territorially speaking. Colonies seemed to be like human beings; the smaller they were, the more sensitive they were, and the more jealous of their dignity. Hong-Kong was particularly jealous of its dignity, whereas the Germans in the north at Kiao-chou had shown much more accommodation towards the Chinese. In Hong-Kong the officials would not allow a junk destined for Canton to be loaded under the eyes of a Chinese Customs officer, fearing that their sovereignty would be interfered with, and that there would be a loss of dignity. The result was that a junk left Hong-Kong fully laden, and when she reached a particular place she was compelled to go ashore and discharge the whole of her cargo on the banks, so that the Customs authorities might take tribute of what was on board. In the case of a railway he did not know what would be done, but he was quite sure that a number of fiscal difficulties of that kind would be experienced at the frontier. Some delay at any rate must be occasioned, because it would be impossible to inspect the wagons full of goods until they arrived at Canton, or else the Customs authorities would have to stop the train and be satisfied that all the goods had paid duty. So far as goods went, he thought there was very little chance of any merchandise being carried by the railway from Canton to Hong-Kong or vice versa.

Mr. Grove, in reply, stated that the loan-agreement called for Mr. Grove. the construction of a first-class single line, as stated in the Paper, but with provision for the eventual construction of a double line. This latter proviso was made subject to the approval of the Chinese authorities. It was decided to acquire land for a double line, with the exception of a length of 6 miles. The rather large area of land acquired was accounted for partly in this way, and partly by the flat low-lying country necessitating very large borrow-pits, as it was not possible to dig to any great depth. In his opinion, it was not wise to pinch land-widths, as land formed a valuable asset of railways in China. Large areas had been provided for the eventual

Mr. Grove. junction with the Canton-Hankow line and at certain station-sites. It was difficult to compute the average quantity of earth or rock moved per coolie from cutting or borrow-pit: labour conditions varied so greatly in China. Petty contractors paid as low a rate as 25 cents per day to their earthwork-coolies. In addition, the contractor paid for housing, importation, sometimes for food, and so forth. The best class of labour would cut, and carry 60 feet, 150 cubic feet per day or more per coolie, and received a higher wage accordingly. The accommodation for platelayers was based on ultimate requirements. Fourteen men in each hut were required for a "green" line, but were rather crowded. The number was now reduced. Several huts had been pulled down and re-erected at stations or halts, armed robberies being frequent. The coolies were not very safe at stations, but they preferred being robbed in good company. The installation of semaphore interlocking signals was believed to be fully justified. Their use was good training for the station- and train-staff, apart from considerations of safety. The arrangement provided that points could not be altered when a train was passing over. In order to arrive at the average cost of works per mile he would prefer to deduct the cost of land, instead of that of rolling stock. The result would be about the same, say, £11,000 per mile. The higher cost of this railway per mile than of the northern lines was, in his opinion, due to the four principal causes already indicated in the Paper, namely—

- (a) The heavy nature of the works, having regard especially to the short length of the line.
- (b) The higher cost of labour and materials.
- (c) Almost constant interruption to the work by armed robbers and similar disturbances.
- (d) The semi-tropical nature of the climate, necessitating the use of first-class timber in sleepers, etc.

Any further comparison seemed unnecessary. As to the manner in which the spans over the larger waterways had been determined, comparative estimates were made, and finally 224 feet spans seemed to meet the conditions most satisfactorily. Waterways were generally trained by the Chinese as the result of centuries of experience, and such training-works, if available, were a good guide. In the case of the East River valley problem, a computation of flow by Kutter's or other formula could not be worked out very satisfactorily, owing to the number of spill-channels and the enormous wetted perimeter, as well as the holding-up effect of the cross bunds. With regard to the units adopted, English measurements,

both lineal and cubic, were given throughout the Paper. Chinese Mr. Grove. fong (100 cubic Chinese feet) measurements had been sometimes adopted for contracts, and this was advisable in some cases. Many contractors were "old railway hands," and were well known to Mr. Grove and his assistants, and there was no trouble over measurements. He agreed with Mr. Ough that heavy rain frequently scoured out a slope badly. The practice, however, of cutting back a slope until it would stand was world-wide, unless expensive retaining-walls were adopted. In Hong-Kong earth certainly stood at an extraordinarily steep batter, being pure gritty decomposed granite; but Mr. Ough was entirely wrong in suggesting that throughout the railway the nature of the earth was the same. Mr. Grove wished it were so. Many very serious landslides occurred on the Chinese section, greatly increasing the cost of earthwork. Only the barest margin of safety was generally provided. Turf grew excellently on 1-to-1 slopes in cuttings. Good results were obtained by plastering bad decomposed rock faces with a mixture of lime, sand, and gritty red earth. Wherever possible (which was only in a few places) slopes steeper than 1-to-1 were adopted. With regard to Mr. Ough's remarks on Chinese contractors, any responsible engineer would be wise to endeavour to break up that most pernicious system of sub-letting. He could only disagree as to the methods advocated by Mr. Ough when a contractor did bad work, as happened too frequently: it must be nipped in the bud, in China as elsewhere. The employment of day-labour was at no time advocated, except where undoubtedly necessary: the reverse was the case.

Mr. BOOTHBY, in reply, stated that the gross load per square foot Mr. Boothby. of bearing surface for No. 2 pier of the East River bridge with train-loads was almost exactly 4 tons. Sinking had been done in most cases with 5-foot circular Batho diggers, worked from twin gallows fixed on the concrete and held down by clamps on the suspension rods. For working the diggers two 3-ton Grafton steam-hoists with $\frac{7}{8}$ -inch diameter wire rope were used, being erected on shore for the shore piers and in an anchored lighter for the river piers; the crown chains were attached to the jib of the gallows so as to discharge automatically into the river clear of the pier. No trouble was experienced from the material under the cant-plate holding up the caisson until the clay overlying the marl was reached. A jointed clay-cutter built up of old rails was then used with some effect, and, when this failed to break down the walls sufficiently, radial holes were drilled in them by divers, and dynamite cartridges were inserted and fired by a rack-bar exploder. The maximum number of cartridges used was eight in each well. In the early

Mr. Boothby. stages of sinking of the river piers, floating cranes, working with the Batho digger or Priestman grab, were used to avoid delay in jacking-up the gallows; when a caisson stuck and the dredging hole got to some distance below the cutting edge, groups of dynamite cartridges were fired in the chamber, and a "run" generally followed the shot. In a few cases the wells were pumped dry, and the final undercutting was then done by hand. With regard to the towing of the caissons from the East River to the Tung Kun River, the depot at the latter bridge was for girder-erection only. In the earlier stages of the work the only depot was at the East River, and it appeared to be a reasonable economy to manage with one jetty and launching-ways for the erection of the caissons. Mr. Boothby had not realized how serious the resistance of the double-octagonal caissons would be when they were towed against even a moderate current, and he had expected to be able to tow them round with two launches; as it was, the expense of an additional jetty and crane and launching-ways was saved at the cost of some trouble in retrieving one caisson which met a sudden flood on its way round. A complete list of the plant used on the works accompanied the original Paper, but had been omitted for lack of space. This, as well as drawings of the pontoon-staging for pitching and gallows for sinking caissons, and of the launching-jetties, pontoons, and staging, could be seen at The Institution. Two pontoons only were used, their dimensions being 60 feet by 50 feet by 7 feet 6 inches deep; the staging on them was 26 feet 6 inches above deck-level, and supported the spans at the second panel-point; the launching weight of the spans was reduced to 332 tons by the omission of the outer rows of floor-plates and most of the overhead wind-bracing. Photographs of the progress of the launching of the last span accompanied the original Paper. The proportions of the concrete used in the steining were 1 part of cement to 3 parts of sand and 6 parts of stone broken to 2-inch gauge; the actual average weight of the concrete was $141\frac{3}{4}$ lbs. per cubic foot. In the weights of the caissons given the curb was included in each case; it formed a portion of the caisson steelwork. The curbs alone were used for shore piers and in places where sand islands could be made, and in these cases the concrete walls were built up from the curb with only temporary timber shuttering. With regard to the comments made by Mr. Ough, it should be remembered that the conditions attaching to contract work in remote places in the interior of China were widely different from those enjoyed in large cities, such as Hong-Kong and Shanghai, where conditions of law and order were fully established. On

the work described it had been impossible to obtain adequate Mr. Boothby. protection for contractors against armed robbers. Mr. Boothby preferred contract to departmental work in most cases in China, but, for work such as caisson-sinking under difficult conditions and the erection of large spans under the conditions adopted, he was not aware of any Chinese contractor who could be relied upon. The contractor for the masonry and concrete of the large bridges was a reliable man who had undertaken erection work on a small scale under the Author in the construction of another railway, but he was afraid to tackle work of which he had not had experience. It would be interesting to know how many bridges Mr. Ough had built in China under the conditions he recommended—of not taking notice of bad rivets until the work was finished. With 30,000 field rivets in each span to be put in, it would be a futile expedient to attempt to make the contractor cut out and replace half of them on completion; and the consequent delay to the completion of the work would obviously be disastrous. The Hong-Kong and Canton riveters were the worst of their kind that Mr. Boothby had met with in China, but by careful supervision and arrangement of sub-contracts the work on the large spans had been carried out efficiently, although several sub-contractors failed in the course of it. In his opinion it was quite as easy to train the Chinese to understand the fong of 100 English cubic feet as the cubic yard, and as a matter of fact the difference between the Chinese and the English fong was perfectly well understood by the contractors and in most cases by their coolies; in all cases that had come under Mr. Boothby's notice the contractors used an English 100-foot tape in measuring the borrow-pits for payment to their coolies. In all contract work on railways in China the greatest pains were taken, and with increasing success, to prevent the sub-letting of petty contracts.

Mr. EVES, in reply, stated that the curves and gradients on the Mr. Eves. British section were the same as on the Chinese section, and this was one of the causes which had made the British section so much more expensive. The large area of land per mile of line was, due to various causes: e.g., (1) the terminal station in Kowloon, which was a rapidly developing part of the British Territory, would eventually become the terminus of the main line from Peking to South China, and land had to be arranged for at the start, as prices were rising rapidly. A total of 69 acres was bought or reclaimed for this purpose in the first 4,000 feet of railway. (2) Anti-malarial measures necessitated the purchase of a great deal of land in the vicinity of the coolie-camps near the portals of the various

Mr. Eves. tunnels. Much cultivated land had to be bought, in order to keep the irrigated areas which formed mosquito-breeding places at a sufficient distance from any houses. These areas would eventually be resold, which would reduce the average. The comparatively short length of line over which these areas had to be distributed made comparisons with other railways difficult. The main plant used for the Beacon Hill tunnel consisted at each side of the following:—Four 30-HP. Lancashire boilers; three Schram air-compressors, each consisting of a steam- and an air-cylinder set tandem, 18 inches in diameter and 24 inches stroke, working to 70 lbs. per square inch air-pressure; three receivers, each of 285 cubic feet capacity and 15 feet by 5 feet in diameter. The rock-drills were $3\frac{1}{2}$ inches in cylinder-diameter. It was calculated that at each side two compressors would be required for the drills, and one for ventilating. However, as the work went on it was found that all three engines could be coupled up to a single 6-inch delivery air-pipe, and the exhaust air was quite sufficient to ventilate the heading while the drills were being used. Before the blasts were let off an air-valve was opened to blow out the smoke. The use of air-drills was considered very economical, as the air served the double purpose of driving the drills and ventilating. If electric drills had been used a separate plant would certainly have been required for ventilating. In addition to the above, at each side were installed two double-cylinder engines coupled direct to 16-kilowatt dynamos for electric lighting. The rolling stock used comprised four metre-gauge locomotives, forty-one steel tip-wagons, twenty wooden trucks, thirty bogies, and forty 2-foot-gauge steel tip-wagons. There were 10,000 yards of metre-gauge track and 1 mile of 2-foot track. The advisability of sinking deep shafts was often questioned. In the present instance the opening of the line for traffic had depended on the completion of the Beacon Hill tunnel. It was also considered likely at the time that the Chinese section would be completed before the British section, and therefore the expense of the shaft was thought to be warranted. As 500 feet of heading was driven from the bottom of the shaft alone, about 100 days were gained directly. Besides which all the material excavated in driving the heading at the north side was brought up the shaft, which relieved the congestion of traffic through the portal. This allowed the widening-out to proceed much quicker at this end of the tunnel. As mentioned by Mr. Ough, the Chinese had a great dislike to labour-saving machinery. Ballast-crushers were used in the construction of the Admiralty dock and were found to be no cheaper than hand-labour. With the large amount of rock-cutting on the

line it was found possible to make depots of hand-broken ballast at very short intervals, and thus the training of ballast was almost entirely avoided. The heavy cost of the minor bridges was due to the height of the banks across the ravines being out of all proportion to the catchment-areas of the streams flowing through the banks. Comparative estimates were taken out for the various waterways required and the cheapest bridge was built. To take a single instance: just outside the north portal of the Beacon Hill tunnel two streams were crossed on a 48-foot bank, requiring a 10-foot waterway each. Two 10-foot surcharged culverts were estimated for, and also a single 20-foot culvert, with the necessary stream-diversions for bringing both streams into one. Finally, three 40-foot girders on pier abutments were found to be the cheapest, the cost being about half that of two 10-foot surcharged arched culverts. The supervision mentioned in the Paper chiefly referred to tunnelling and cutting-excavation. The cuttings were mostly on sharp curves and steep gradients. Chinese coolies understood perfectly making banks from borrow-pits in the open country, but cuttings were new to most of them. Coolies imported from the north were not a success, on account of the dampness of the Hong-Kong summer months. North China had a much dryer heat, and the coolies from those parts were not as clean in their habits as those in the south. Washhouses were provided for the tunnel-coolies, but they could not be persuaded to use them.

Tunnel No. 1	cost	\$507·42	per lineal foot by contract.				
" "	3	247·48	" "	departmental labour.			
" "	4	400·92	" "	" "	"	"	
" "	5	327·14	" "	" "	"	"	

Mr. Ough had taken exception to the slopes. This matter had been always a bone of contention in the colony during the construction of the railway. When roads, etc., necessitated cuttings in the colony, the slopes were invariably left very steep. This had the advantage, as Mr. Ough had remarked, of offering a very small surface to the falling rain; but, on the other hand, falls were very frequent. However, as there was no wheeled traffic in Hong-Kong, no damage or delay ensued, as the foot-passengers climbed over the obstruction, which was often left for weeks without any outcry being made. That sort of thing, however, could not be allowed on a railway, as the delay caused while clearing such falls of the side slopes would mean great financial loss when the competition with the river-steamers was so keen. The danger due to boulders embedded in the decomposed granite shaking loose under the

Mr. Eves. vibration of passing trains had also to be borne in mind. The location of the line outside Kowloon station had been settled by other than engineering considerations. Just to the west of the line was a public park, which it was out of the question to spoil by running a line through it. The longer alignment mentioned by Mr. Ough had been considered and surveyed, but had been rejected on account of the extra running-expenses which would be entailed. The main traffic was in passengers between the terminal stations of Kowloon and Canton, and it had been rightly considered of paramount importance to keep the distance between these two points as short as possible. Mr. Byron Brennan had drawn a very gloomy picture of the future prospects of the railway, which Mr. Eves was glad to hear was not justified. He had been given to understand that a satisfactory agreement dealing with the customs duties was drawn up before the revolution broke out, but owing to the unsettled state of the country nothing could be done since. He had no doubt, however, that no difficulties would be put in the way of a satisfactory settlement by either the Hong-Kong or the Chinese Government when the matter came up again. In conclusion, he desired to thank the members for the kind way in which they had received and discussed his Paper.

Correspondence.

Mr. Baker. Mr. R. BAKER, of Kowloon, remarked that there was no doubt the British section was a costly line to build, the fact that more than $7\frac{1}{2}$ per cent. of its length was in tunnel speaking for itself. It was difficult to compare the cost with that of other railways, because, while the formation and the bridge-masonry had been built for double line, track and bridge ironwork for single line only had been provided so far. Moreover, as a Government undertaking it was difficult to compare it with a commercial enterprise. No ordinary railway-company could have built skew bridges of 60 feet span over proposed roads, could have borne the heavy expense of bridge No. 2, or could have accepted debit for the cost of raising and regrading the roads and sewers in the neighbourhood of the reclamation. No private enterprise would have taken the railway through cutting No. 1, about 4,000 feet long, 200 feet deep at the deepest point, and containing the 30 million cubic feet necessary for the reclamation, when the reclamation itself was admittedly far too big for present requirements, though it would undoubtedly be a valuable